Effect of Thermal Processing of Wheat and Barley Dietary Fibers on the Bioavailability of Carbohydrates

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Abstract
Cereal grains are major sources of dietary fiber (DF), an important component of food and an important contributor to human health. Based on their water solubility DF are classified as soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). The physical and physiological properties of dietary fibers are of commercial and nutritional importance. Food processing is mostly based on heating. Heat treatment alters the properties of plant cell wall and modifies the composition and solubility of fibers. The experiments had in view the effect of dry heat treatment (in forced air oven, and microwave oven) on the bioavailability of carbohydrates. The research investigated the dynamics of released glucose (RG) from heat treated whole wheat and barley flour, during *in vitro* gastric and intestinal digestion. RG after 240 minutes of intestinal digestion revealed a higher digestibility of carbohydrates in wheat samples heated at 150°C for 10 and 15 minutes and in barley samples heated for 5 minutes. When the heating time of the barley samples was longer, the digestibility of carbohydrates decreased due to the formation of higher starch resistant to amylase action. Carbohydrates digestibility of wheat samples exposed to microwaves was lower compared with untreated samples. We observed a moderate increase in carbohydrate digestibility in barley samples after microwave exposure for 30 and 60 seconds. The digestibility decreased after 90 seconds of microwave exposure, due to accelerated Maillard reactions and increase in the proportion of resistant starch.

Keywords: wheat, barley, dietary fiber, thermal processing, released glucose, refractive index, digestion

1. Introduction

Cereal grains are major sources of dietary fiber (DF), an important component of food and an important contributor to human health. Cereal grains contain 66–76% carbohydrates. The major carbohydrate is starch (55–70%), followed by minor constituents, such as arabinoxylans (1.5–8%), β-glucans (0.5–7%), sugars (~3%), cellulose (~2.5%), and glucofructans (~1%) [1-6].
DF consists of non-starch polysaccharides and other plant components such as cellulose, resistant starch, resistant dextrins, inulin, lignins, chitins, pectins, beta-glucans, and oligosaccharides. In cereal grains with high concentrations of non starch polysaccharides (NSP), water soluble arabinoxylans (AXs) and β-glucans are responsible for increased intestinal viscosity, and reduced starch, fat, and protein digestibility [7].
Rye, barley, oats, wheat, and triticale are "viscous grains" as they contain considerable amounts of soluble NSPs, whereas corn, sorghum, millet and rice, which contain negligible amounts of soluble NSPs, are known as "non-viscous cereals" [8,9].
Cereal grains contain various amounts of NSP depending on the species and tissue type [2]: 1.14 g kg^{-1} in wheat kernel, 1.32g kg^{-1} in rye and 1.67g kg^{-1} in barley. AXs represent the main non-cellulosic NSP component in wheat (0.6-0.8g kg^{-1}) and rye (0.89g kg^{-1}), while β-glucans are the predominant NSP in barley (0.76g kg^{-1}) [10-13]. The molecular weight of β-glucans is higher than

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that of AX, and both polymers contribute to the viscosity of the extract [14].
Exogenous carbohydrases are used when feed ingredients contain relatively high amounts of NSP [15-17]. Previous researches show that soluble NSP increased *in vivo* intestinal viscosity and slowed down the rate of diffusion of substrates, digestive enzymes, and final products of digestion, and therefore affect the digestion and utilization of nutrients [18-22].
Consumption of whole grain cereals results in a slow increase in blood glucose compared to refined flour consumption [23,24], although some results suggest otherwise [25]. The mechanism by which whole grains could reduce the rapid increase in blood glucose is not yet clear [26]. The presence of soluble NSPs is thought to negate starch hydrolysis and glucose uptake by increased viscosity.
Based on their water solubility DF are classified as soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). The physical and physiological properties of dietary fibers are of commercial and nutritional importance.
Only the part that is soluble or that becomes soluble by hydrolysis or other physic-chemical changes can be taken up in circulation and used by the animal as a building material or as a source of energy [27].
Food processing is mostly based on heating. Heat treatment alters the properties of plant cell wall and modifies the composition and solubility of fibers.
The experiments had in view the effect of dry heat treatment (in forced air oven, and microwave oven) on the bioavailability of carbohydrates. The research investigated the dynamics of released glucose (RG) from heat treated whole wheat and barley flour, during *in vitro* gastric and intestinal digestion

2. Materials and methods

Samples of whole meal flour were digested *in vitro*, according to the method of Boisen et al. [28] with some modifications [29]. The experiments were conducted with the two-step pepsin-pancreatin procedure which involves sample incubation with pepsin at 37°C and pH 2 for 120 minutes, followed by the incubation with pancreatin at 37°C and pH 6.8 for 4 hours.
The released glucose (RG) was determined from the supernatant obtained after centrifugation. The glucose content was determined using a Glucose Assay kit (GAGO-20, Sigma Chemical Company, St. Louis, USA) and a PerkinElmer UV/VIS-Lambda35 spectrophotometer.

Statistical analysis

Average values, standard deviations, and variance coefficients were calculated. For continuous variables, the regression analysis was performed and the determination coefficients R^2 have been calculated. The results were statistically analyzed using the t-test. Significant differences were reported when $P \leq 0.05$.

3. Results and discussion

RG after 240 minutes of intestinal digestion revealed a higher digestibility of carbohydrates in wheat samples heated at 150°C for 10 (WT 2) and 15 minutes (WT 3) (Figure 1), and in barley samples heated for 5 (BT 1) and 10 minutes (BT 2) (Figure 2). When the heating time of the barley samples was longer, the digestibility of carbohydrates decreased due to the formation of higher starch resistant to amylase action.

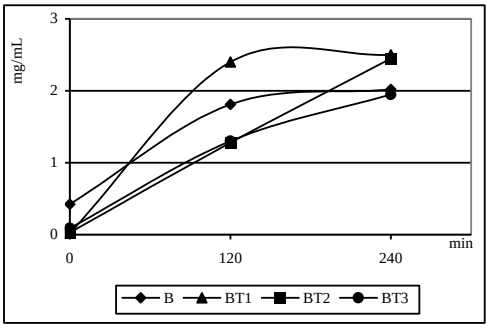

Figure 1. *In vitro* RG of thermal processed wheat

Carbohydrates digestibility of wheat samples exposed to microwaves (Figure 3) was lower compared with untreated samples (W). We observed a moderate increase in carbohydrate digestibility in barley samples (Figure 4) after microwave exposure for 30 (BM 1) and 60 seconds (BM 2). The digestibility decreased after 90 seconds of microwave exposure (BM 3), due to accelerated Maillard reactions and increase in the proportion of resistant starch.

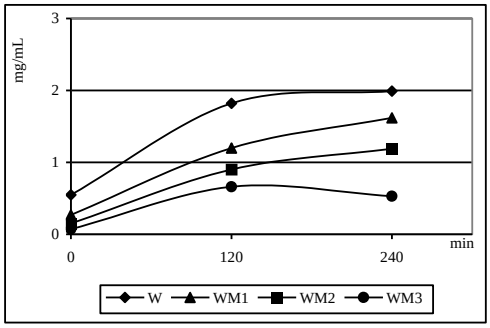

Figure 2. *In vitro* RG of thermal processed barley

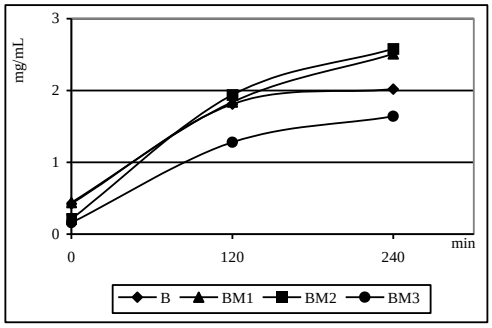

Figure 3. *In vitro* RG of microwave processed wheat

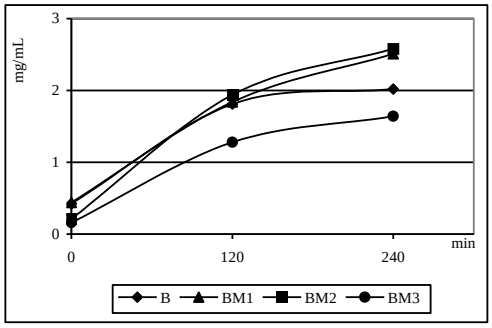

Figure 4. *In vitro* RG of microwave processed barley

4. Conclusions

Short thermal processing modifies the physical and chemical structure of DF, facilitating accessibility of enzymes to carbohydrates and improving their bioavailability. The solubility of the fibers and especially the gelatinization of the starch can improve the digestibility of the carbohydrates

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